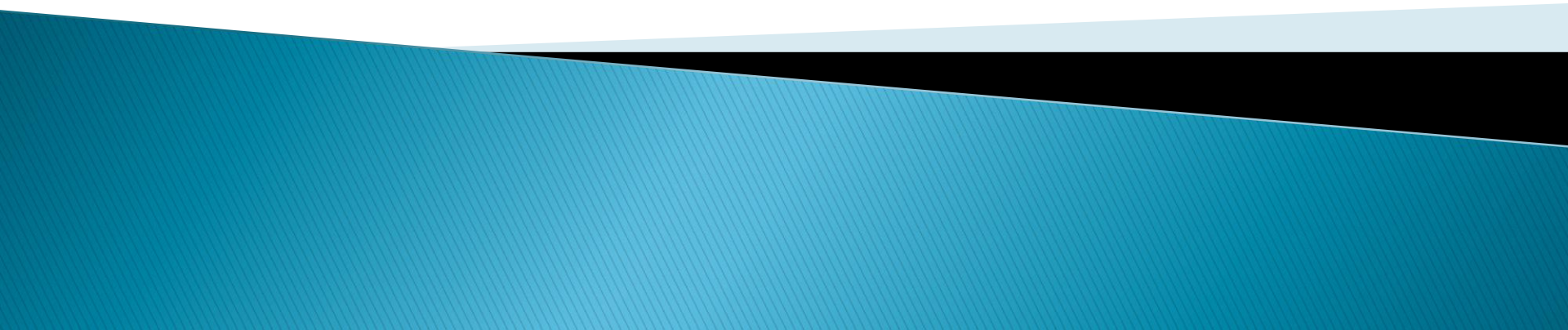


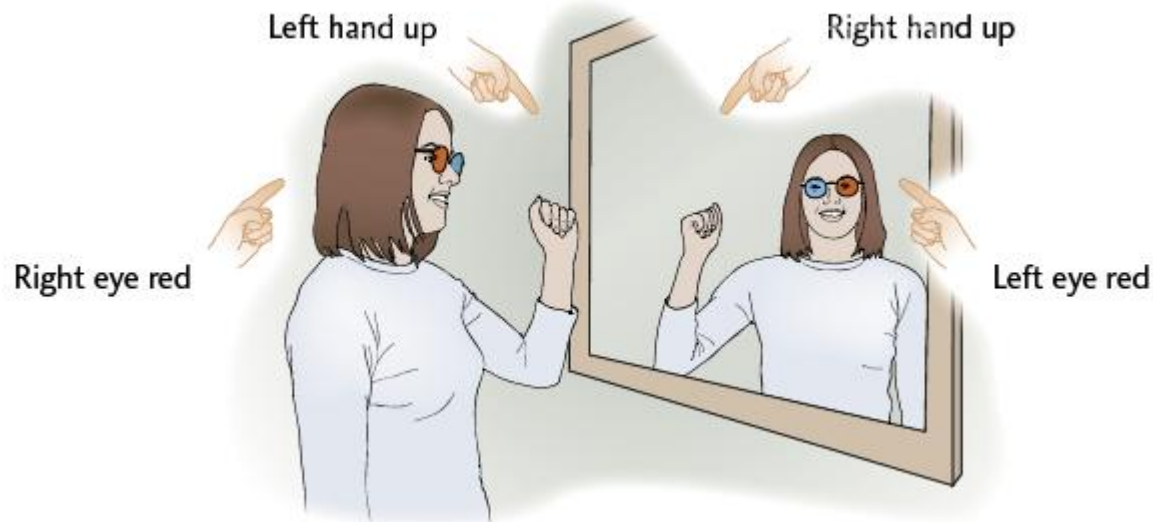
Light and Geometric Optics

Mr.V



Optics

- ▶ The branch of physics which studies light



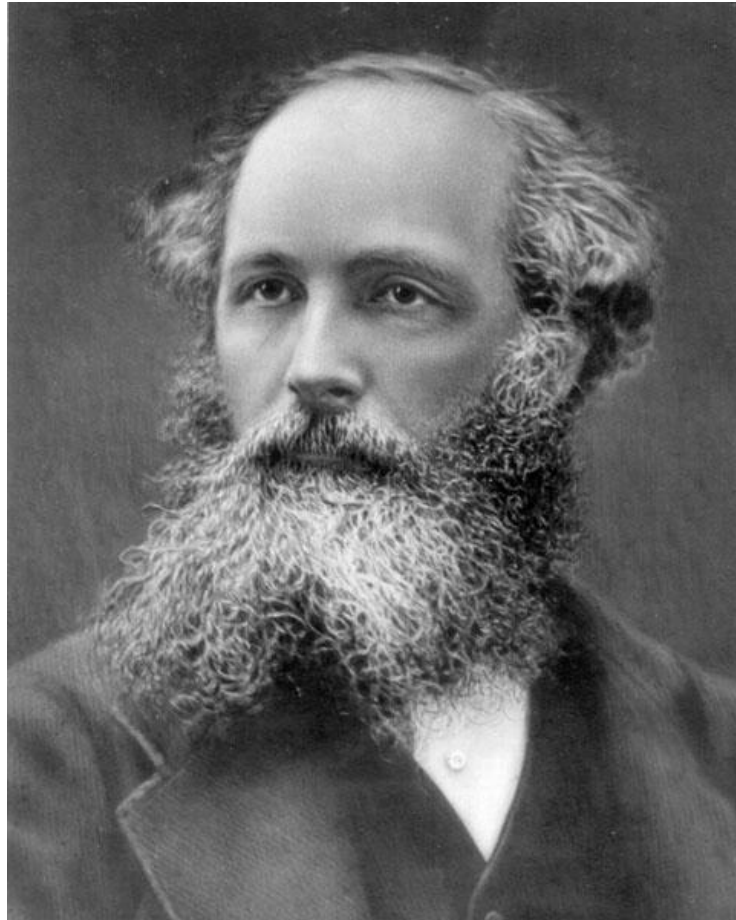
Models of Light

- ▶ Geometric model XVI century by W Snell



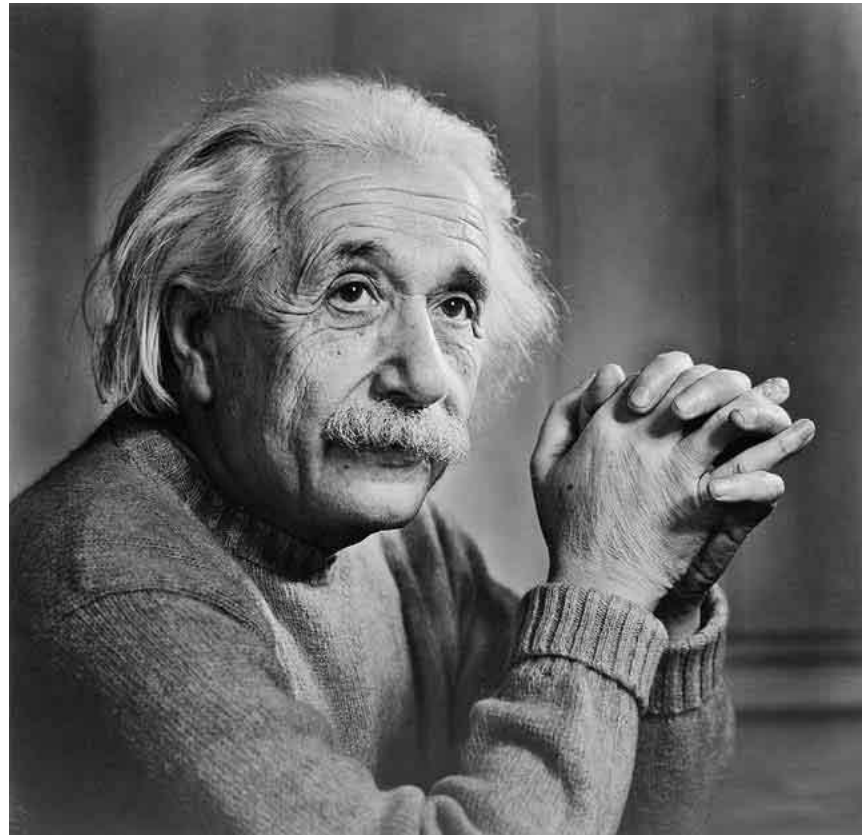
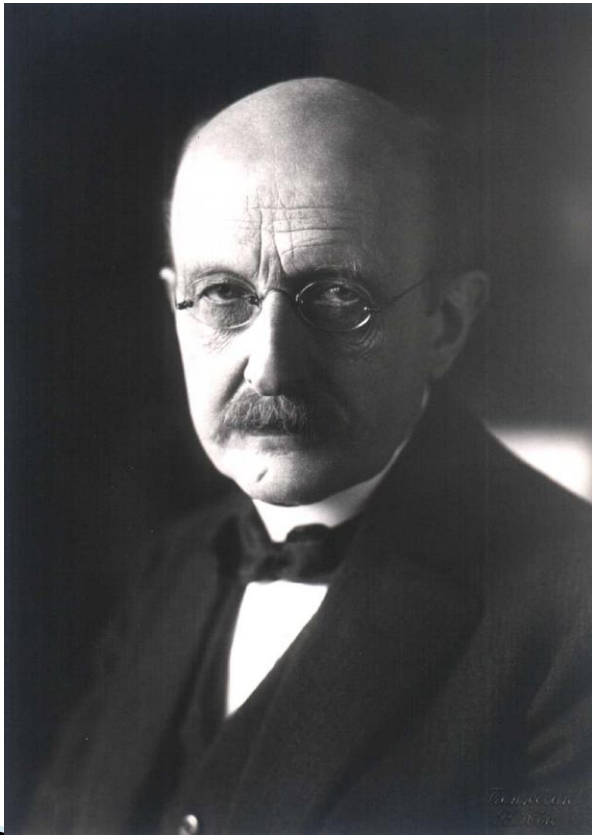
Models of light

- ▶ Wave Model XIX century by JC Maxwell



Models of light

- ▶ Photon Model XX century by Planck, Einstein



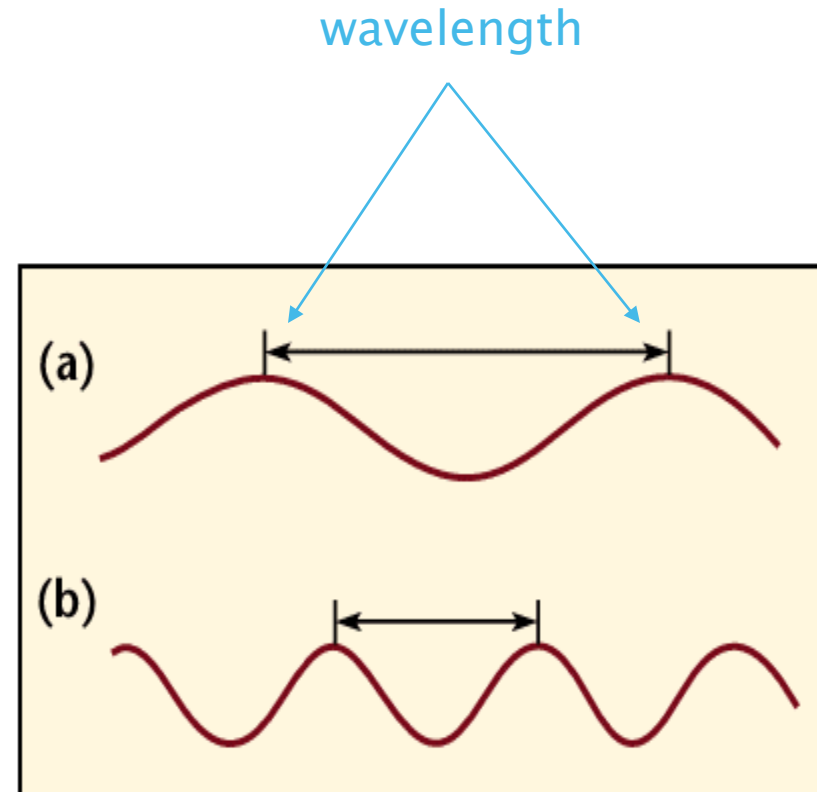
Comparing Models

Models of Light	Basic Concept	Laws and Characteristics	What is explained
Geometric Model	Ray Light = Stream of rays	Snell's Laws based on geometry	<ul style="list-style-type: none">•Rectilinear propagation•Reflection•Refraction•Formation of images through lenses
Wave model	Wave Light = electromagnetic waves	Electromagnetic Theory <ul style="list-style-type: none">•Wavelength 'λ'•Frequency 'f'	<ul style="list-style-type: none">•All of the above +•Diffraction•Interference•Polarization
Photon Model	Photon Light = is a stream of photons.	Quantum Theory Photon is tiny particle with energy, but no mass	<ul style="list-style-type: none">•How light is produced (LASER effect)•Rectilinear propagation•Reflection•Black body radiation•Photoelectric and Compton effect

What is light really?

Electromagnetic radiation waves

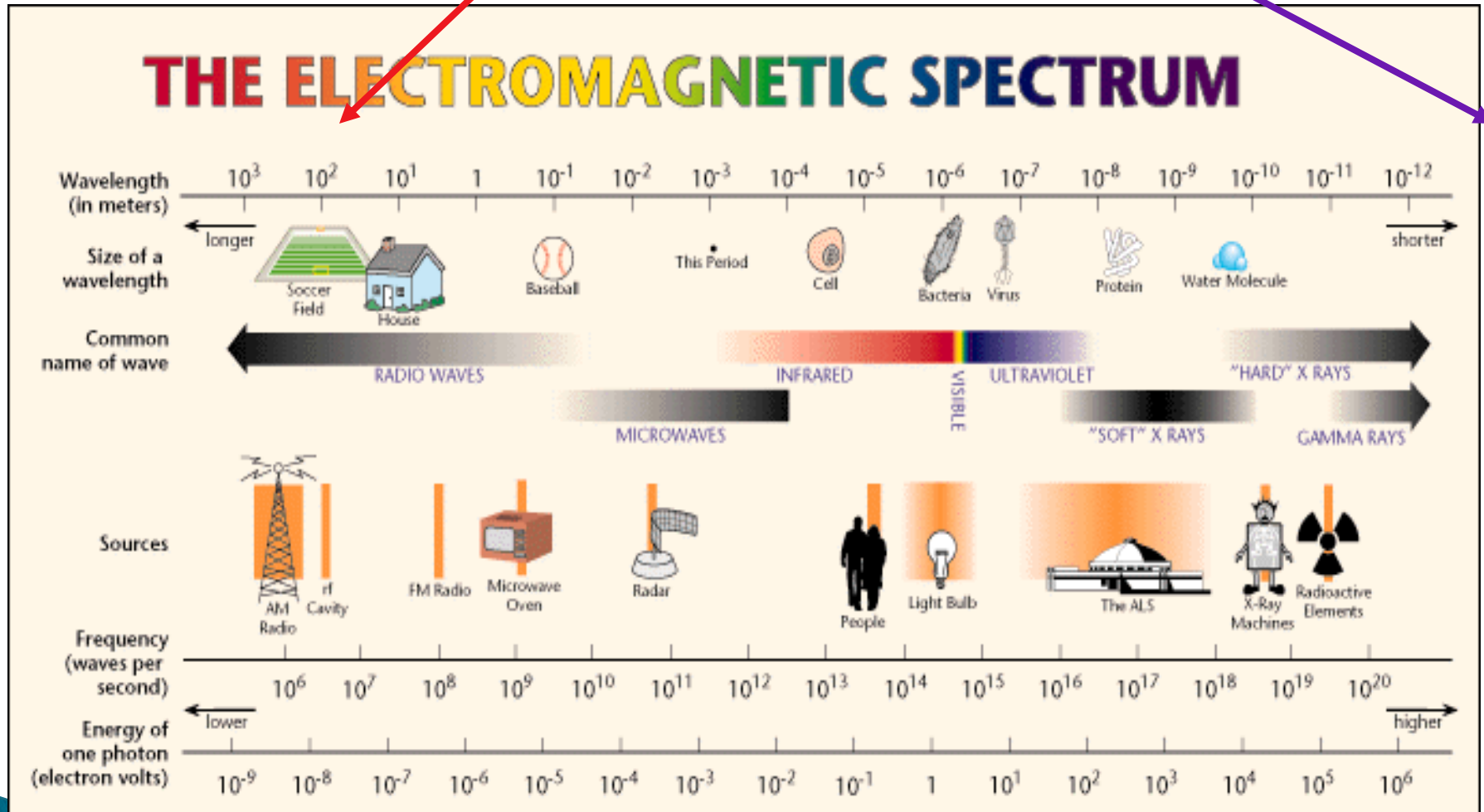
- ▶ Light waves are three dimensional.
- ▶ Light waves vibrate in all planes around a center line.
- ▶ The waves have high points called “**crests.**”
- ▶ Waves also have low points called “**troughs.**”
- ▶ *The distance from one crest to the next crest is called a “**wavelength.**”
- ▶ *The number of waves passing a given point in one second is called the “**frequency.**”



Electromagnetic Radiation

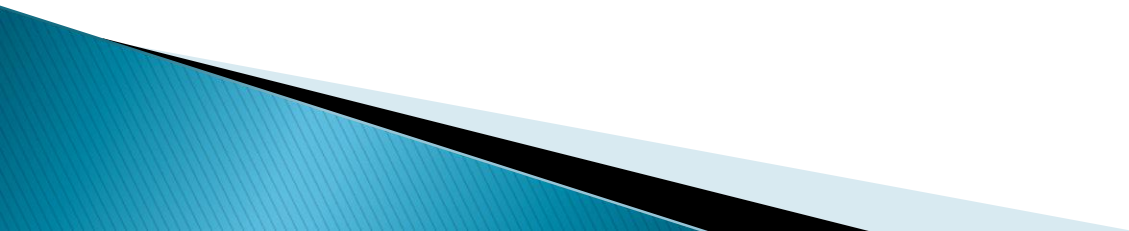
- ▶ Electromagnetic radiation can be described as a stream of photons. Each photon traveling in a wave-like pattern, moving at the speed of light and carrying some amount of energy.
- ▶ The only difference amongst radio waves, visible light, and gamma-rays is the amount of energy of the photons. Radio waves have photons with low energies. Microwaves have a little more energy than radio waves. Gamma-rays and cosmic rays have highest energy waves and are the deadliest.

Don't forget...longest waves (radio) ..to shortest waves (cosmic)



What is light?

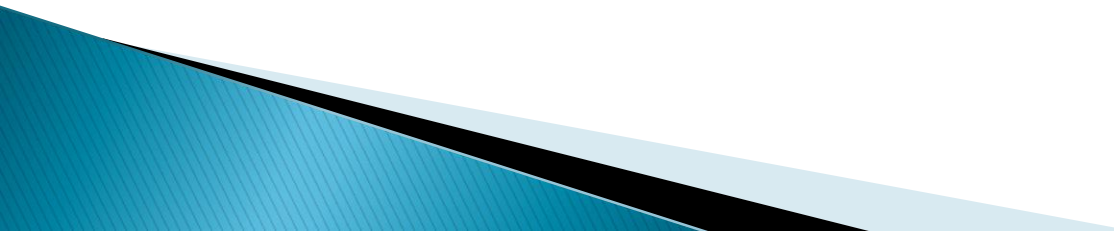
- ▶ Light: A form of radiant energy that the eye can see
- ▶ What are some other forms of energy
- ▶ Name some.....



Sources of light

- ▶ Direct : Luminous objects that produce their own light
 - Examples
- ▶ Indirect: Non-luminous objects do not produce their own light, they reflect a luminous objects light.
 - Examples

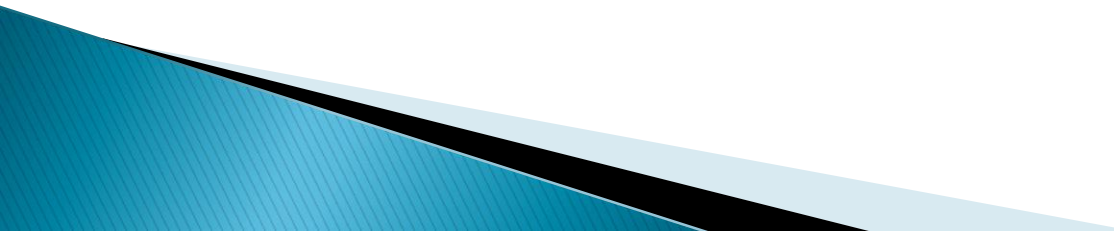
Incandescent light

- ▶ Incandescent Sources: When materials are heated light is produced this form of light is called incandescent light.
 - ▶ e.g
 - ▶ Sunlight
 - ▶ Light bulb
 - ▶ Molten metals (Molten iron)
- 

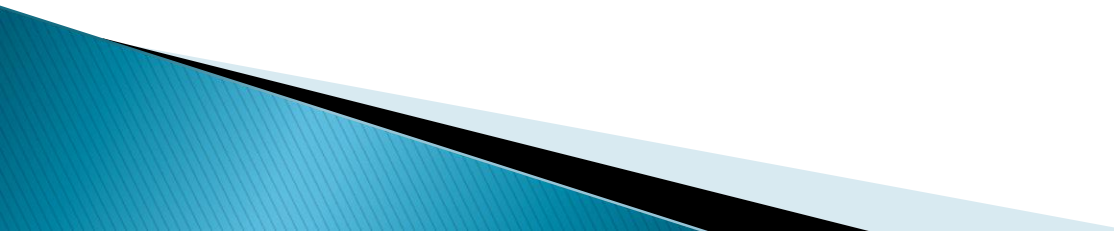
Phosphorescent sources

- ▶ Certain materials called phosphors gain energy from the surroundings and emit the extra energy that it has absorbed.
- ▶ The glow lasts for several hours
- ▶ Luminous dials of certain watches and clocks

Fluorescent source

- ▶ A fluorescent source is a material that emits light only during the time it receives energy from another source
 - ▶ Example:
 - ▶ Neon lamps
 - ▶ Fluorescent light bulbs (look up)
 - ▶ It is four times as efficient as an incandescent bulb
 - ▶ It is 20% efficient
- 

Interaction of light with matter

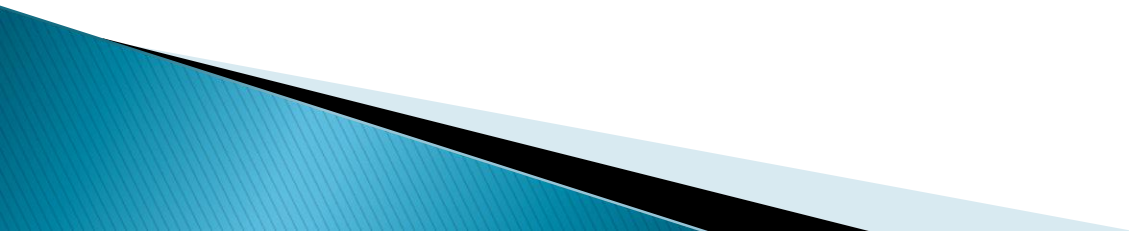
- ▶ Light can interact with matter. Matter can be of three kinds
 - ▶ Transparent
 - ▶ Translucent
 - ▶ Opaque
- 

Transparent

- ▶ A transparent material: allows light to pass through example. Water, clear plastic, glass etc.

Translucent

- ▶ A translucent material: allows some light to pass, light is scattered example Frosted glass, stained glass, shower materials etc.



Opaque

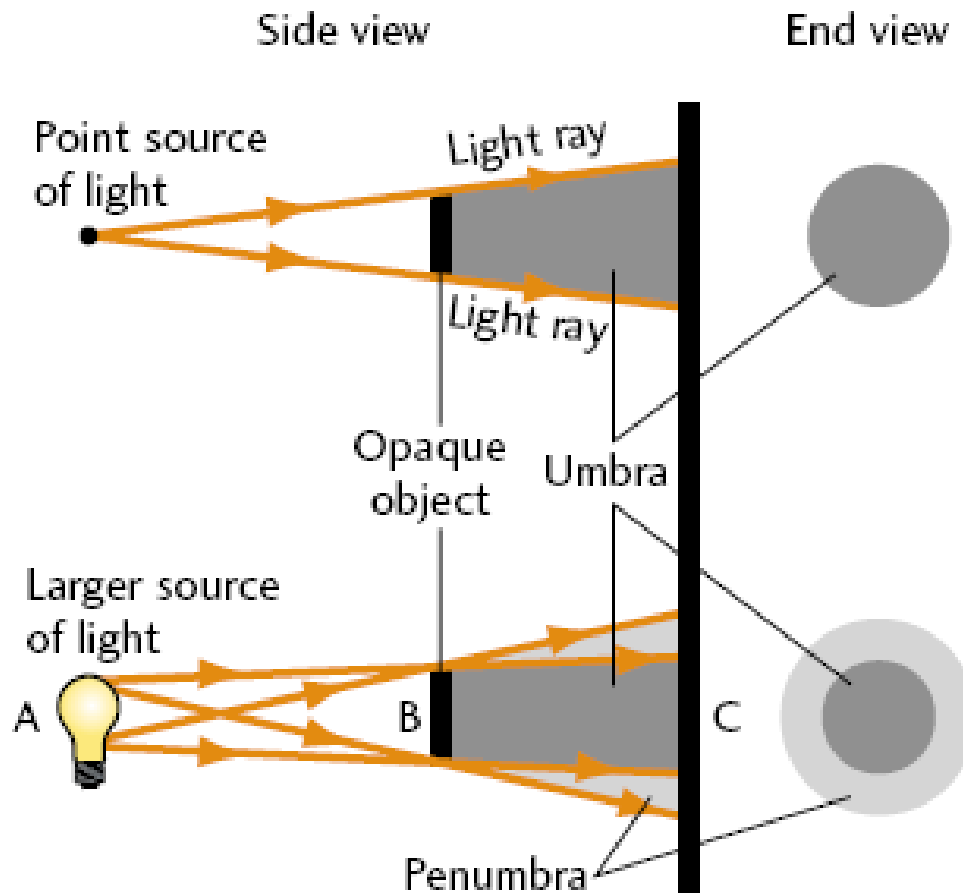
- ▶ An opaque material: does not allow any light to pass through example wood, stone, rock etc.

Characteristics of Light

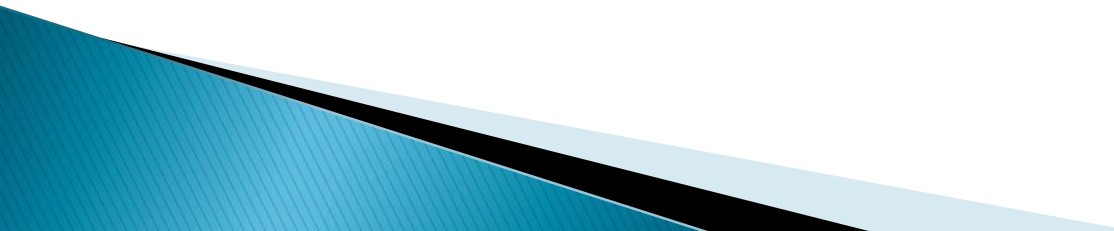
- ▶ **Rectilinear Propagation:** Light appears to travel in straight lines through a uniform medium
- ▶ (Uniform medium means air of uniform temperature and humidity through which light travels)
- ▶ **Proof:**
 - Creation of shadows
 - Creation of upside images

Creation of Shadows

- ▶ Creation of shadow with point source of light



Creation of Shadows

- ▶ A point source of light can cause shadows when it falls on an opaque body.
 - ▶ **Umbra:** The region where light cannot reach is called umbra (A point source of light is needed)
 - ▶ **Penumbra:** The region where there is a mixture of light and shadow.(A large source of light is needed)
- 

Pin hole camera:

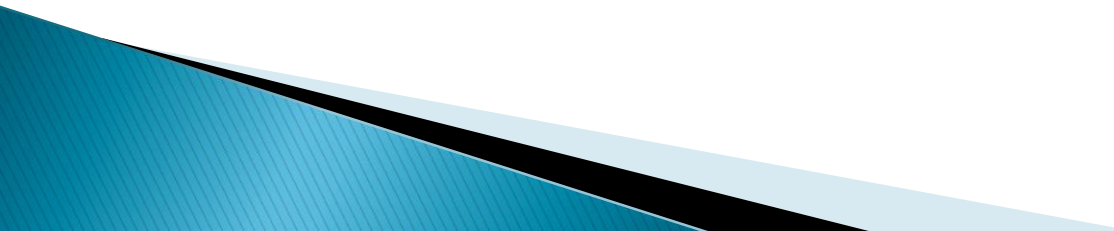
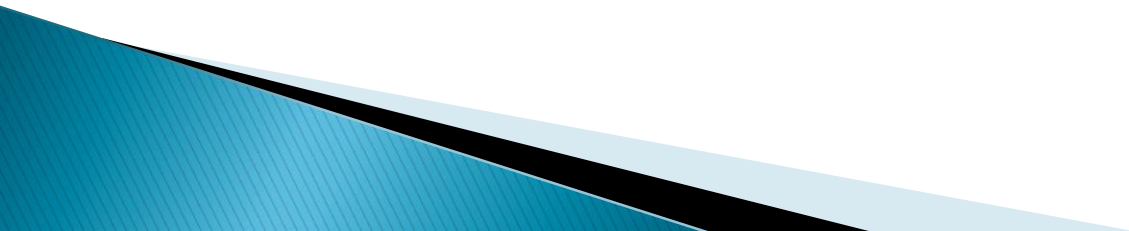
- ▶ Q1. What do you see when you look through a pin hole camera?
 - ▶ Q2. Do you have a lens in the pin hole camera?
 - ▶ Q3. What is the need for a translucent glass in the pin hole camera?
 - ▶ Q4. Explain the formation of the inverted image on the translucent screen. Draw diagrams.
- 

Image formed by pin hole camera

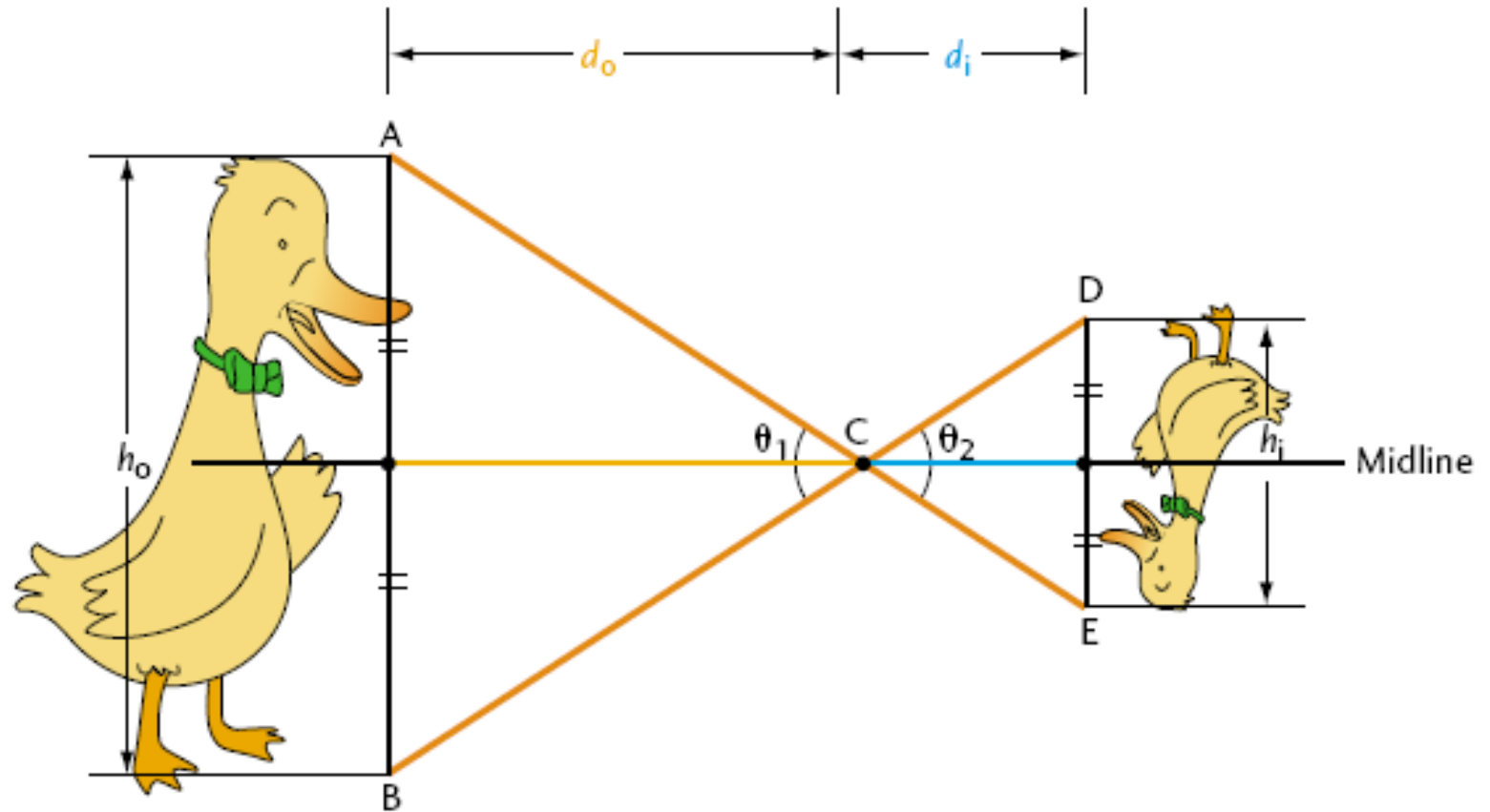
- ▶ Two types of image
 - Real image: Images that can be projected on a screen
 - Virtual images: images that cannot be projected on a screen
- ▶ Description of image
 - Image is inverted
 - Image is smaller than object
 - Image is real

What is the proof that light travels in straight lines (Rectilinear)

- ▶ Creation of upside down images
- ▶ Creation of shadows



Pinhole camera



Magnification

$$\theta_1 = \theta_2$$

Image and object are equally divided
by the midline

$$\therefore \overline{AC} \text{ is equal to } \overline{BC}$$
$$\overline{DC} \text{ is equal to } \overline{EC}$$

$\triangle ABC$ and $\triangle DEC$ are similar,

$\theta_1 = \theta_2$, and both are isosceles

$$\therefore \frac{\frac{d_o}{2}}{\frac{h_o}{2}} = \frac{\frac{d_i}{2}}{\frac{h_i}{2}}$$

$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

This effect is called magnification.

Magnification

- ▶ Equation for magnification

$$\frac{H_i}{H_o} = \frac{D_i}{D_o}$$

- ▶ $i = \text{image}$ $o = \text{object}$

Negative magnification

- ▶ If the image is inverted and the magnification is 0.2 it is written as -0.2 indicating that the image is inverted.

Problem

A pinhole camera of length 30 cm is used to take a picture of a person standing 5.0 m away. If the photograph produced a 10 cm image, what is the magnification of the camera and how tall is the person?

Solution

Solution and Connection to Theory

Given

$$d_i = 30 \text{ cm} = 0.30 \text{ m} \quad d_o = 5.0 \text{ m} \quad h_i = 10 \text{ cm} = 0.10 \text{ m} \quad h_o = ?$$

$$m = \frac{d_i}{d_o} \quad m = \frac{0.30 \text{ m}}{5.0 \text{ m}} = 0.06$$

This figure is used to find the height of the object.

$$m = \frac{h_i}{h_o} = 0.06 \quad h_o = \frac{h_i}{m} = \frac{0.10 \text{ m}}{0.06} = 1.7 \text{ m}$$

The person is 1.7 m tall.

Alternate solution

ALTERNATIVE SOLUTION

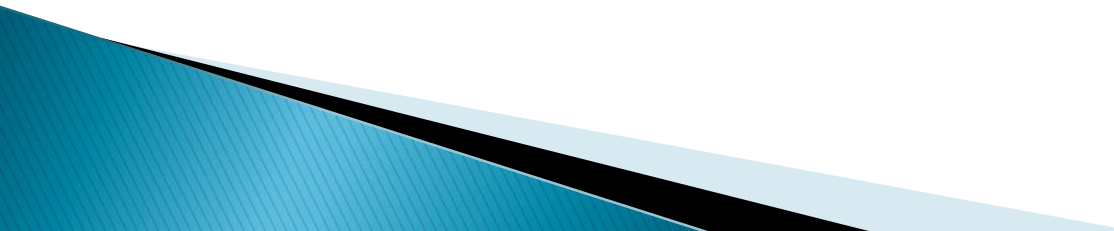
$$\text{Since } m = \frac{h_i}{h_o} = \frac{d_i}{d_o},$$

$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

$$\frac{0.1 \text{ m}}{h_o} = \frac{0.3 \text{ m}}{5.0 \text{ m}}$$

$$h_o = \frac{5.0 \text{ m}(0.1 \text{ m})}{0.3 \text{ m}} = 1.7 \text{ m}$$

Home Work

1. Calculate the magnification of a pinhole camera if
 - a) the height of the object is 12 m and the height of the image is 2.5 cm.
 - b) the length of the pinhole camera is 30 cm and the distance of the object from the camera is 5.5 m.
 2. Calculate the size of the image if
 - a) the magnification is 0.05 and the object is 3.0 m tall.
 - b) the object is 4.4 m tall and is 6.0 m away from a camera, length 25 cm.
- 

Reflection

Plane mirror reflection and images

Terminology

Reflection

Rays and Beams

- ▶ **Ray:** a directed straight line representing the path followed by the light
- ▶ **Beam:** a bundle of rays

Types of light beams:

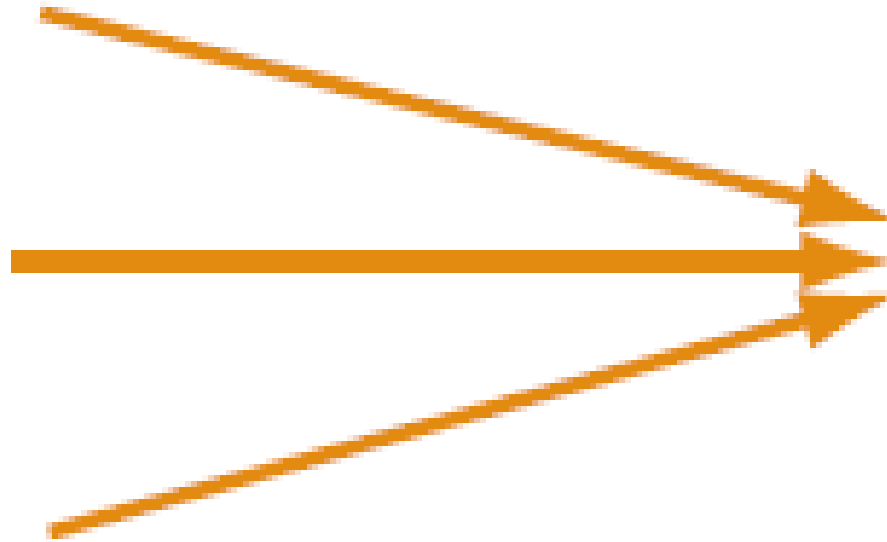
- ▶ Parallel beams:
 - ▶ Converging beams:
 - ▶ Diverging beams:
-
- ▶ Do not copy this slide

Parallel beams



Parallel

Converging beams

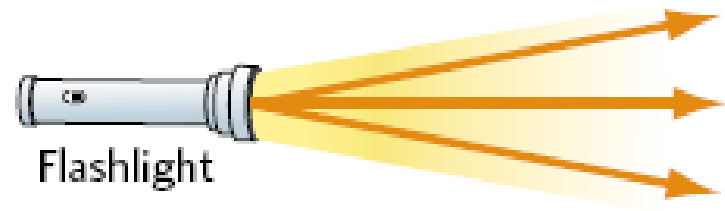


Converging

Diverging beams



Diverging



Incident ray

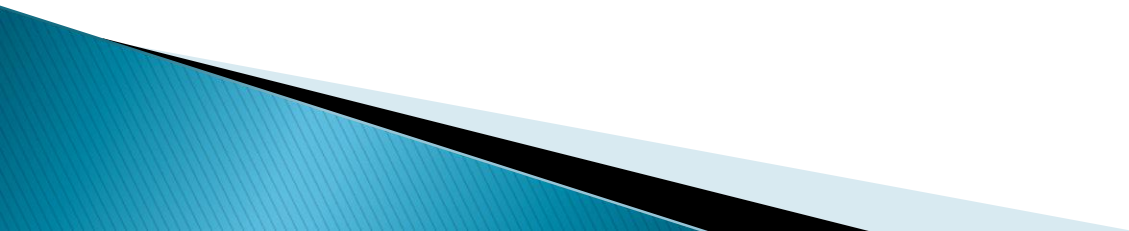
- ▶ The ray of light approaching the reflecting surface.

Reflected ray

- ▶ The ray of light leaving the reflecting surface

Point of incidence

- ▶ Point where the incident ray strikes the reflecting surface



Normal (N)

- ▶ A line perpendicular to the reflecting surface at the point of incidence

Angle of incidence (i)

- ▶ The angle between the incident ray and the normal

Angle of reflection (r)

- ▶ The angle between the reflected ray and the normal.

Laws of reflection

1. The angle of incidence is equal to the angle of reflection
2. The incident ray, normal and reflected ray all lie in the same plane

Types of Images

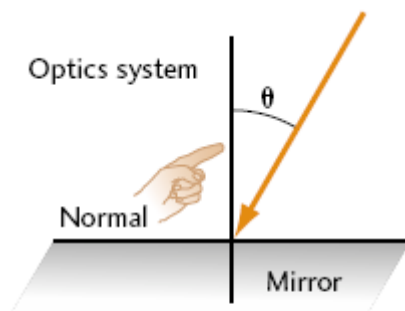
- ▶ **Real Image:** Light comes directly from this kind of image to the eye. This kind of image can be projected onto a screen
- ▶ **Virtual Image:** Light does not really come from this kind of image but only appears to be. This kind of image cannot be projected onto a screen

Reflection

- ▶ Normal: It is the line drawn perpendicular to the plane of reflection (e.g. the surface of the mirror)
 - Two systems for measuring angles

Optics System

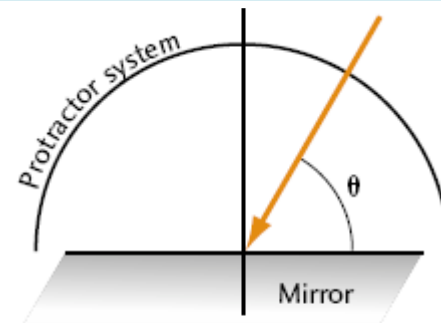
Measure from the normal



Optics system
 $\theta = 30^\circ$
(measured relative to
the normal)

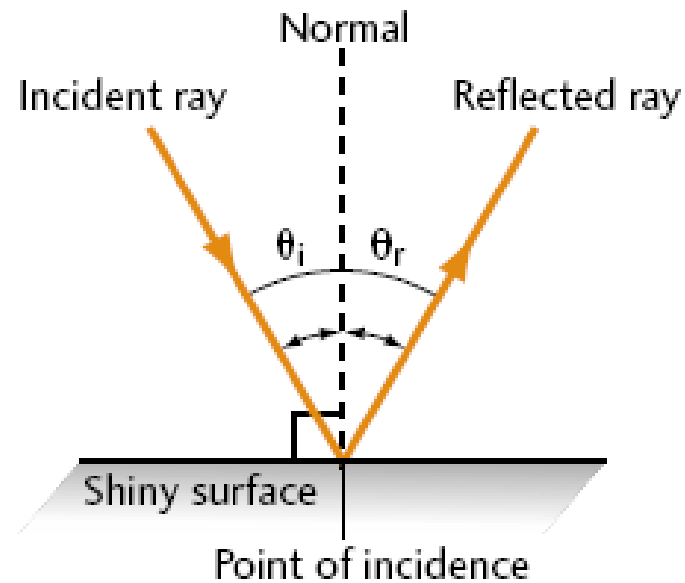
Protractor system

Measures from the x-axis



Protractor system
 $\theta = 60^\circ$
(measured relative to
the horizontal (0°))

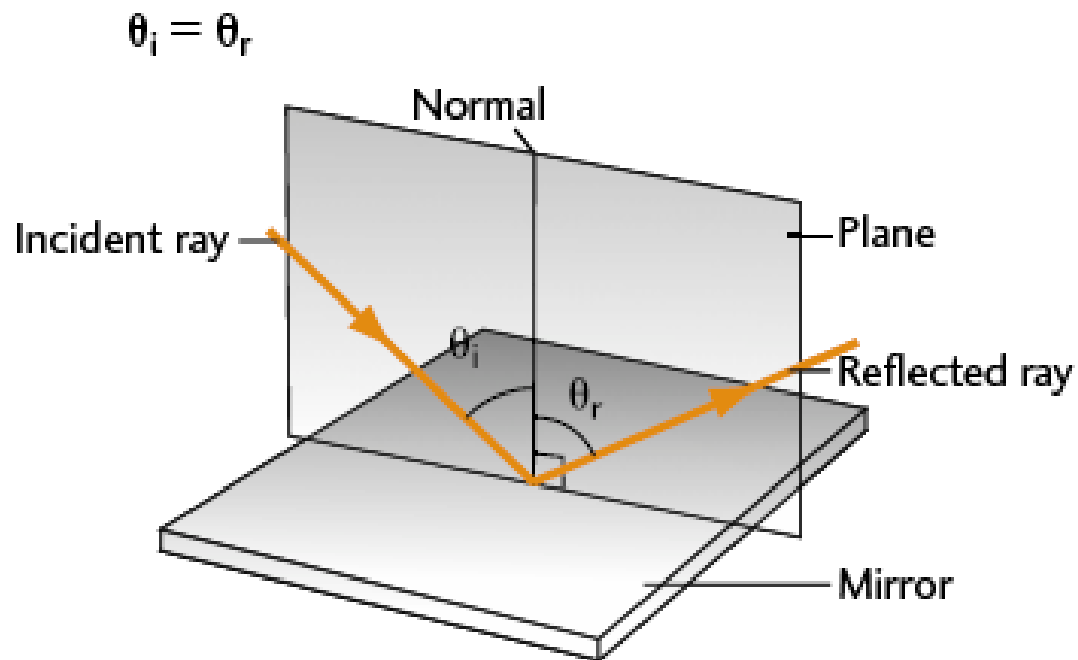
Reflection – Drawings



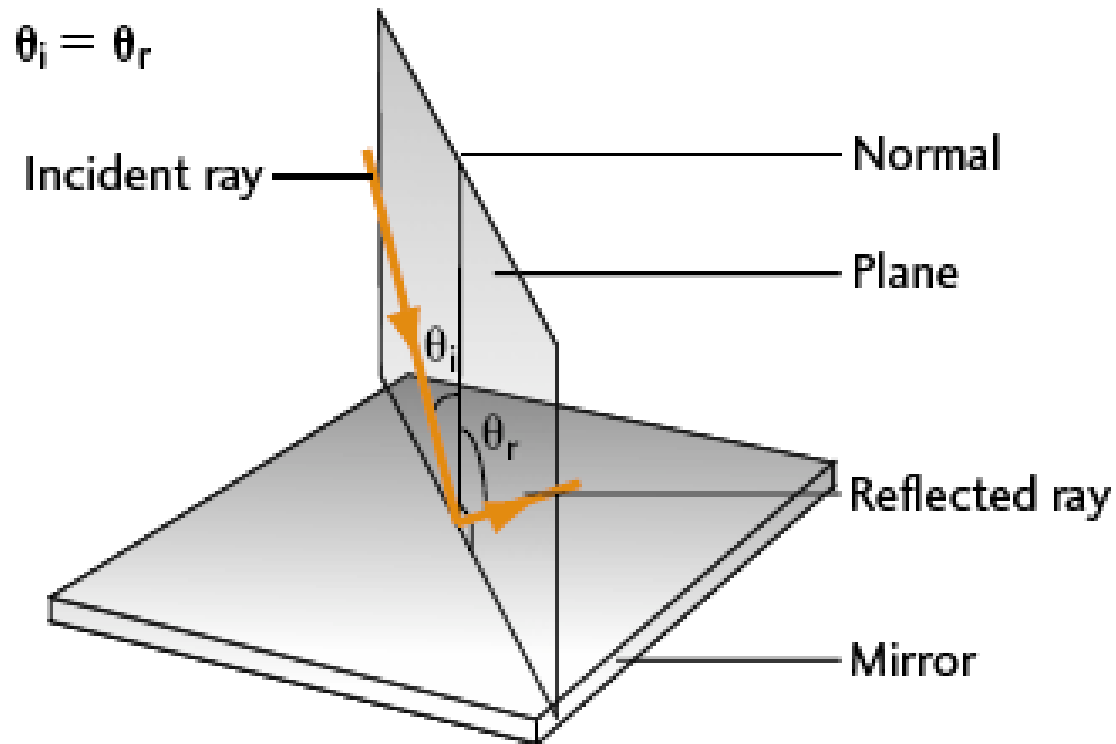
θ_i → Angle of incidence

θ_r → Angle of reflection

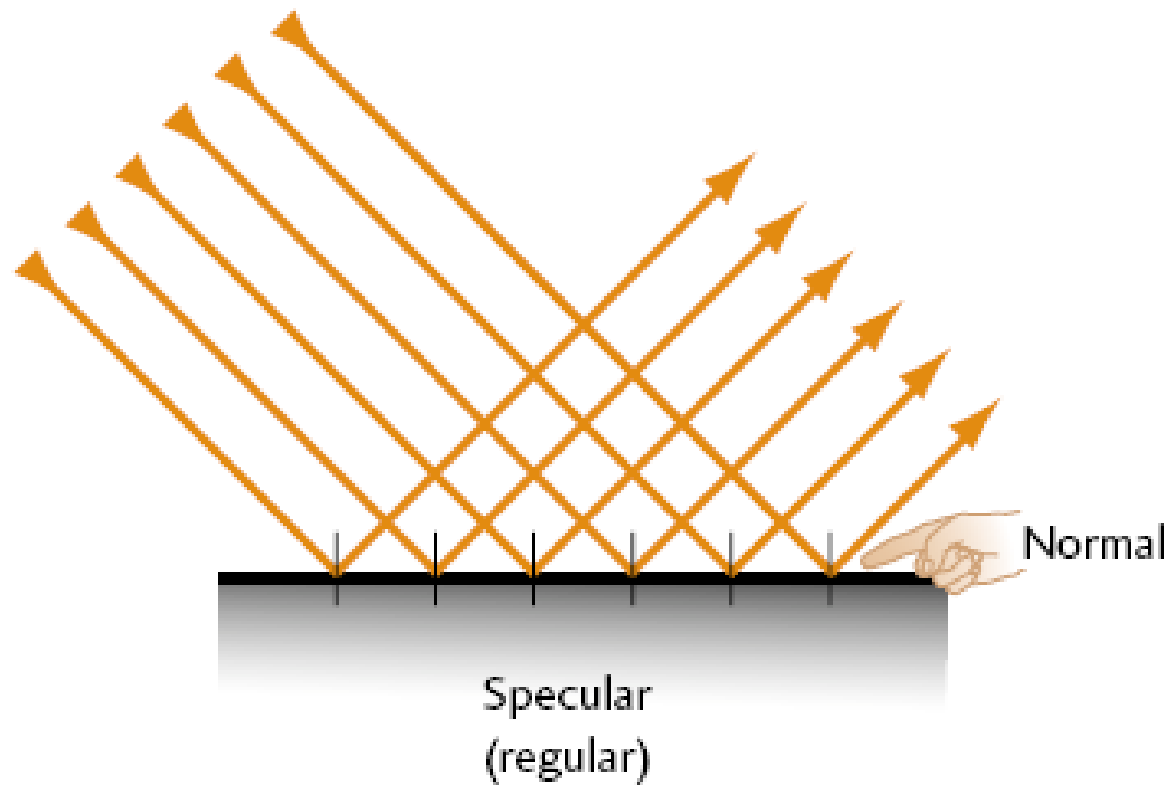
Reflection another perspective



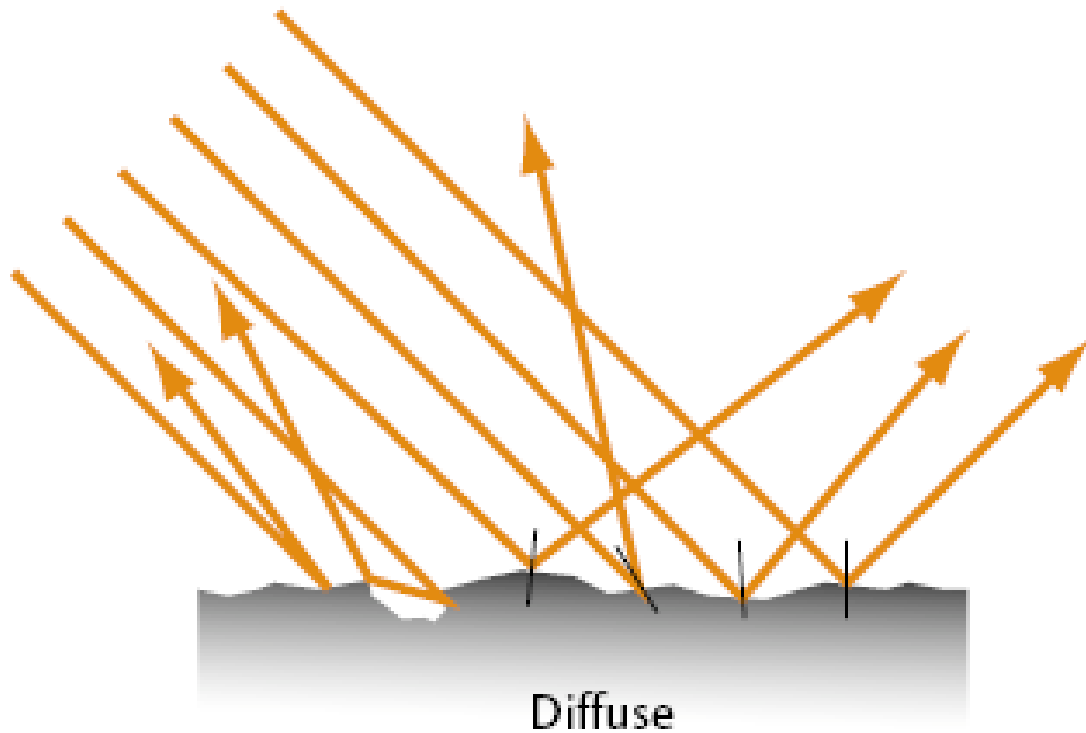
Reflection contd....



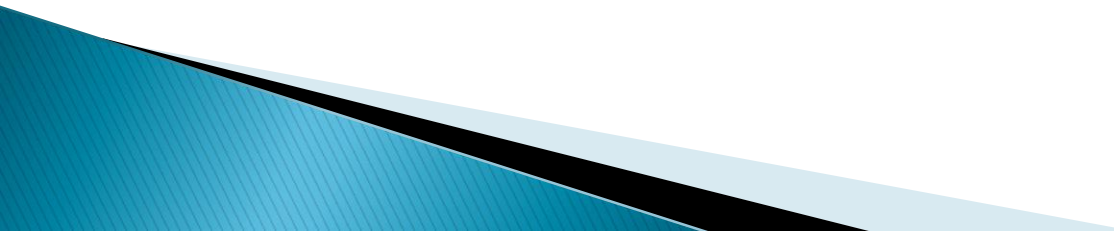
Specular reflection



Diffuse reflection



How to describe the image characteristics

- ▶ Describe the kind of image as **real** or **virtual**
 - ▶ Describe the **magnification** of the image as **enlarged** , **same sized** or **diminished**
 - ▶ Describe the attitude of the image as either **erect** (upright) or **inverted** (upside down)
 - ▶ Describe the **position** of the image as a displacement measured from the reflecting surface (with displacement on the opposite side of the mirror from the object being negative)
- 

Describing an image an example

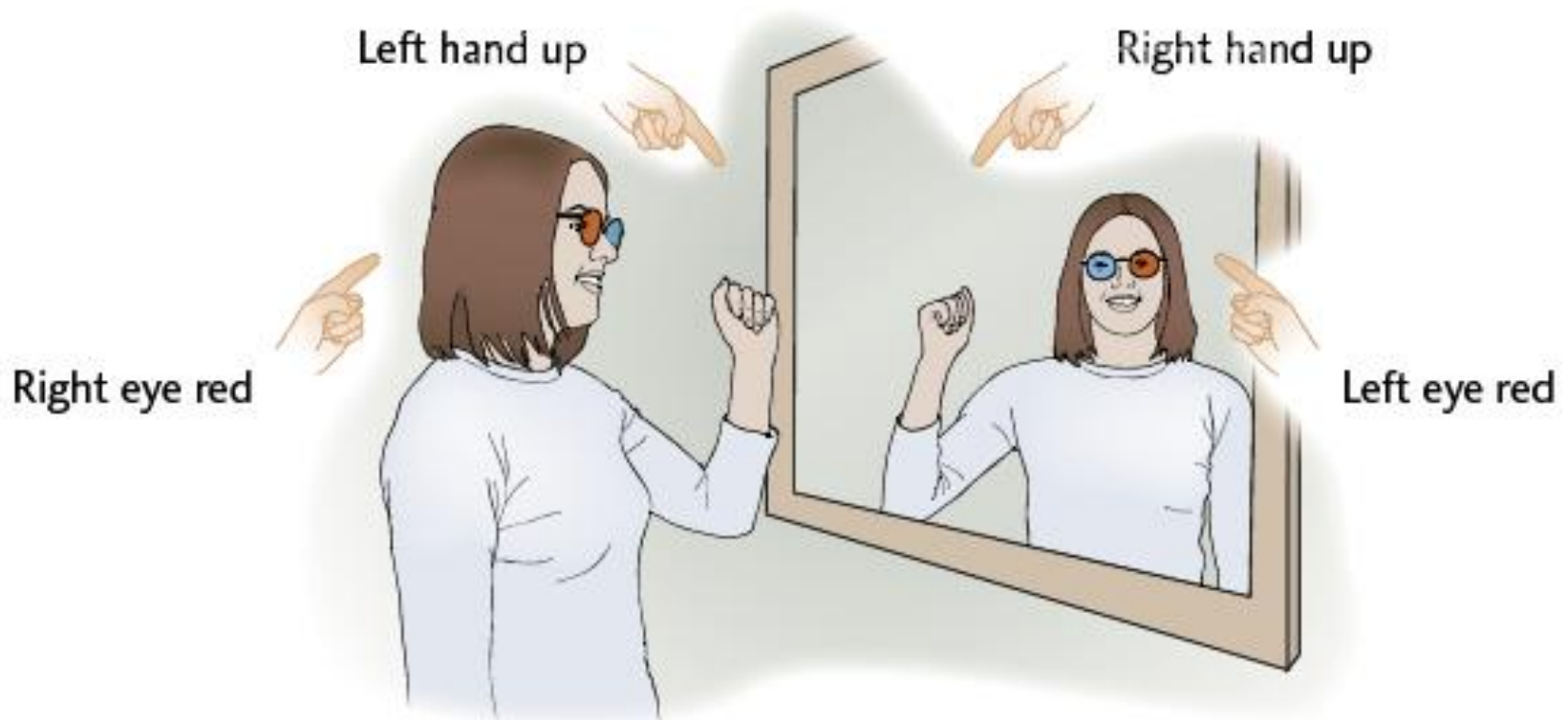
- ▶ The image in a single plane mirror is **virtual**, **same size** and **erect**.
- ▶ Note: That although it is not inverted it is ***perverted***, that is, it is flipped horizontally.

Activity – Lab

- ▶ Complete the sheet formation of image
- ▶ Reflection from a plane mirror simple lab

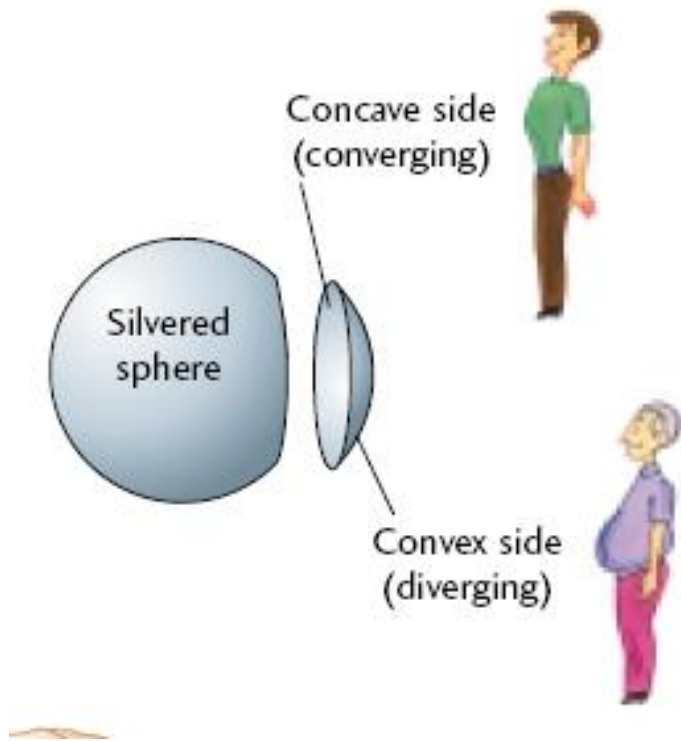
Lateral inversion

- ▶ Images you see in the mirror are they inverted?



Quiz

1. How would you describe the characteristics of an image formed by a mirror?
2. Draw the image formed by the pin hole camera and explain how rectilinear propagation of light can explain it.
3. Define the following terms
 1. Normal
 2. Incident ray
 3. Virtual image



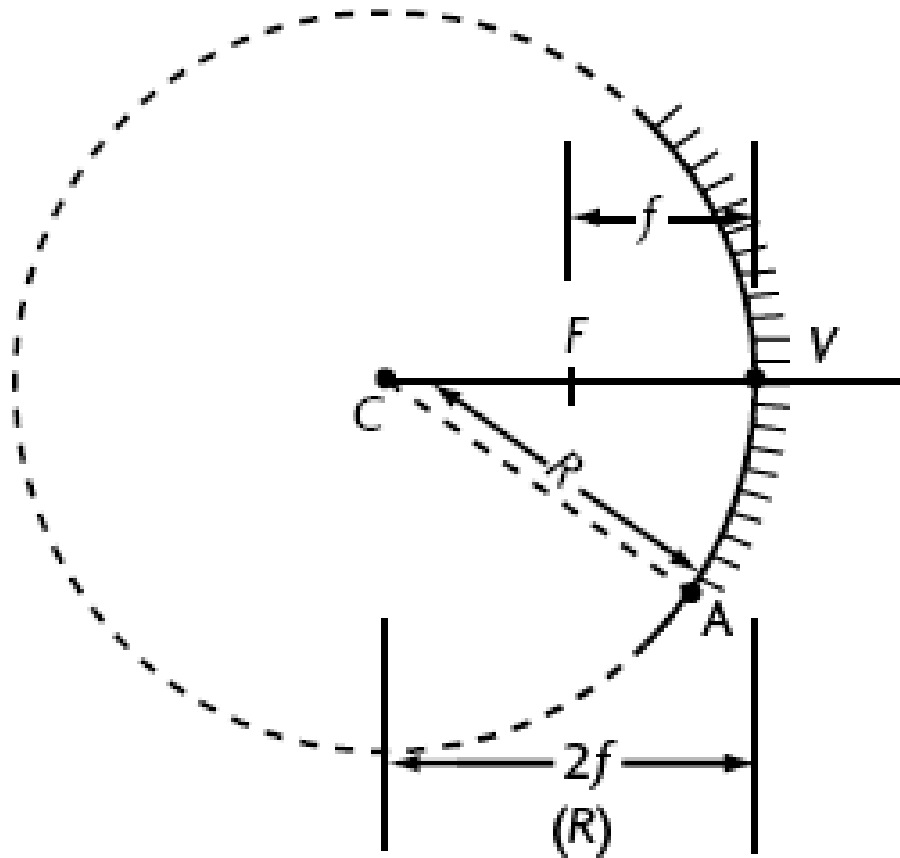
Curved Mirrors

Concave and Convex

Types of curved mirrors

- ▶ Concave
- ▶ Convex

Curved Mirrors



$C \rightarrow$ Centre of curvature

$F \rightarrow$ Principal focus

$FV = f =$ Focal length

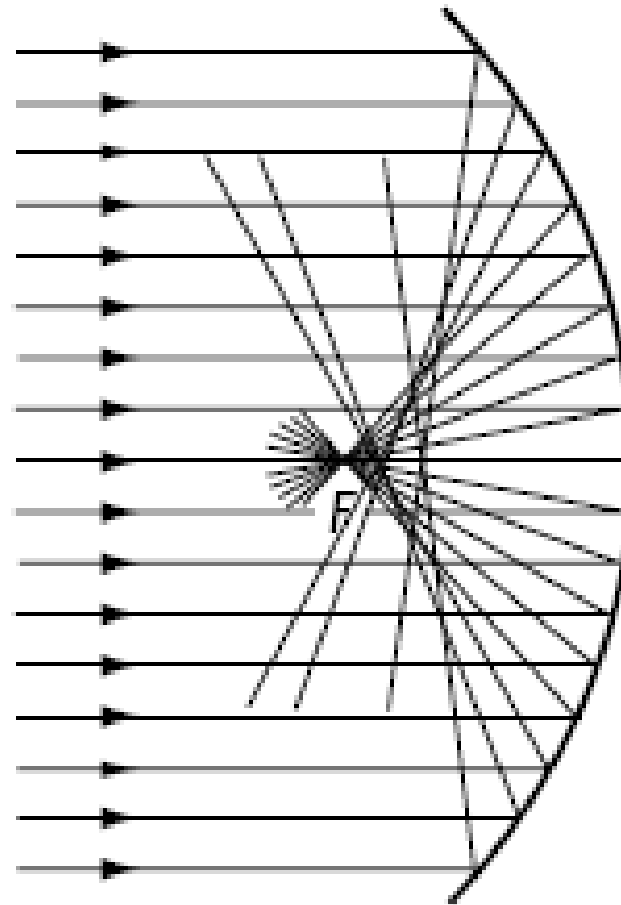
$(2f = R)$

$V \rightarrow$ Vertex

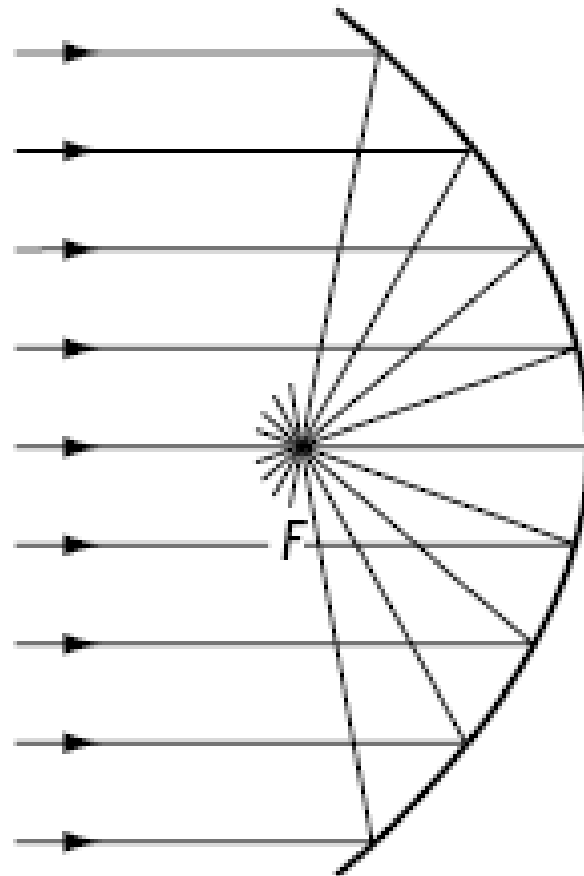
$CV \rightarrow$ Principal axis

$CA \rightarrow$ Secondary axis

$R \rightarrow$ Radius of curvature



Sphere



Parabola

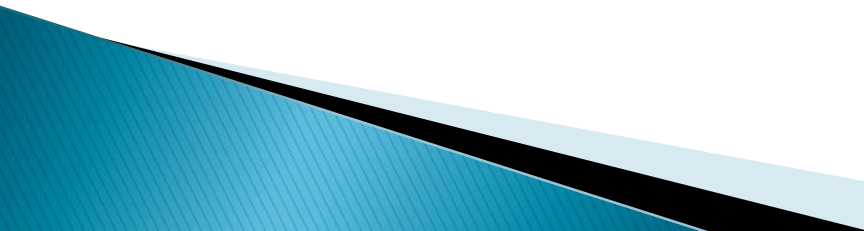
Parts of a curved mirror

- ▶ V: Vertex
- ▶ C: Centre of curvature
- ▶ F: Principal focus
- ▶ FV: Focal length (f)
- ▶ R: Radius of curvature $R = 2f$

Normal

- ▶ For converging and diverging mirrors
- ▶ The ray that passes through the center of curvature is considered a normal.
- ▶ The tangent drawn to this line is used to indicate that the angle is at 90°

Lab activity – Ray diagrams

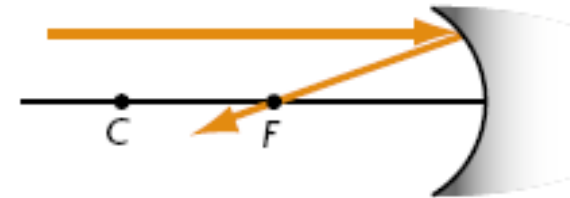
1. Using a ray box observe and draw the path taken by a ray of light travelling through the principal axis (PA) to a concave mirror.
 2. If the ray is parallel to the principal axis what path would a single ray take?
 3. If a beam of three rays are used draw the path taken by the three rays
 4. Repeat experiment with five rays.
 5. From the above diagrams calculate the focal length 'f' of the mirror.
 6. If an object is placed before the centre of curvature where would the image be formed draw ray diagrams.
- 

Ray diagram

1. If the ray is parallel to the principal axis what path would a single ray take?

Parallel to
principal axis

Through focus



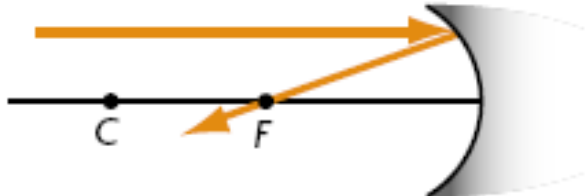
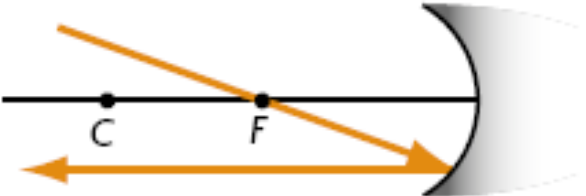
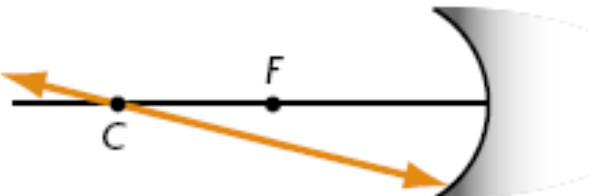
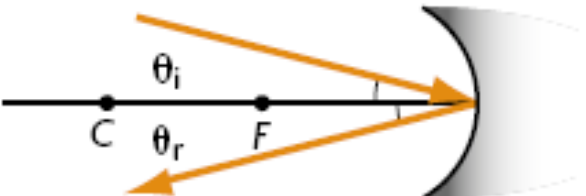
Draw ray diagrams

1. Incident ray parallel to PA are reflected through F (principal focus)
2. Incident rays passing through F are reflected parallel to PA
3. Incident rays passing through C are reflected back through C
4. Incident rays to V (Vertex) are reflected back according to laws of reflection

Note:

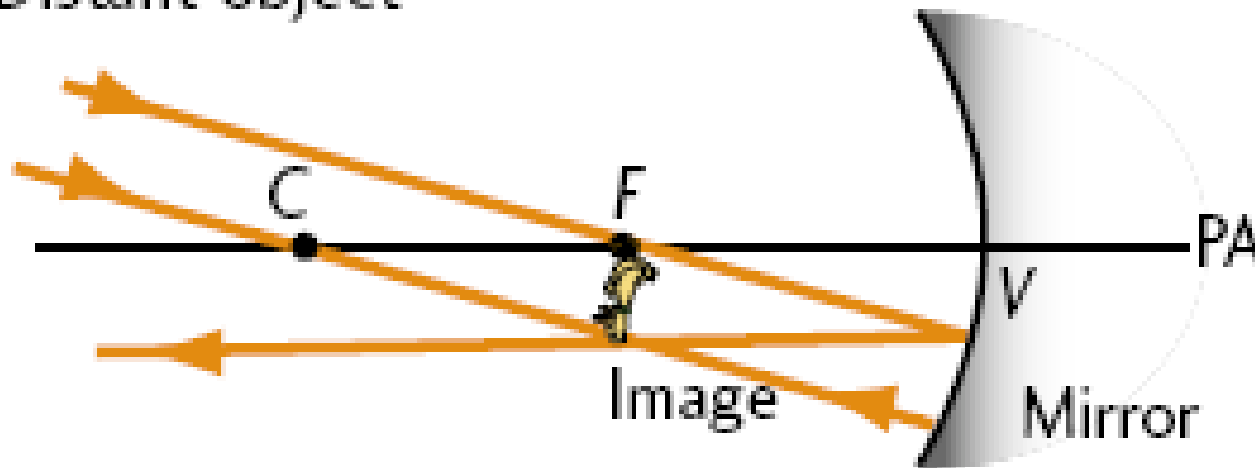
- ▶ The point of intersection of all of the above four rays is where the image is formed
- ▶ Images formed in concave mirrors can be either real or virtual and upright or inverted, depending on the location of the object

Ray diagram for converging mirrors – Concave mirror

Incident ray	Reflected ray	Diagram
Parallel to principal axis	Through focus	
Through focus	Parallel to principal axis	
Through centre of curvature	Back through centre of curvature	
To vertex	Point acts like plane mirror ($\theta_i = \theta_r$)	

Images formed by

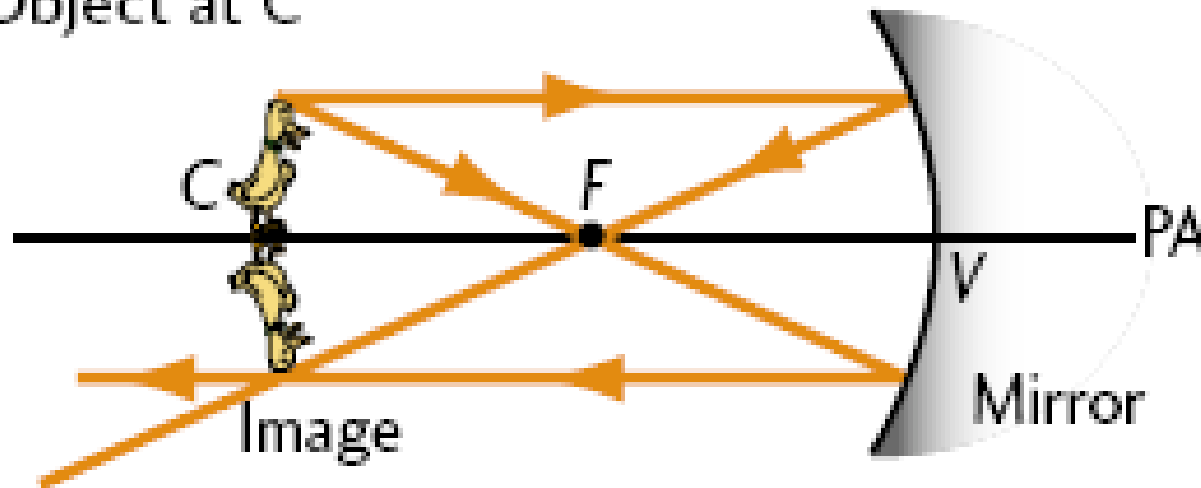
Distant object



Real
Inverted
Smaller
than
object
At F

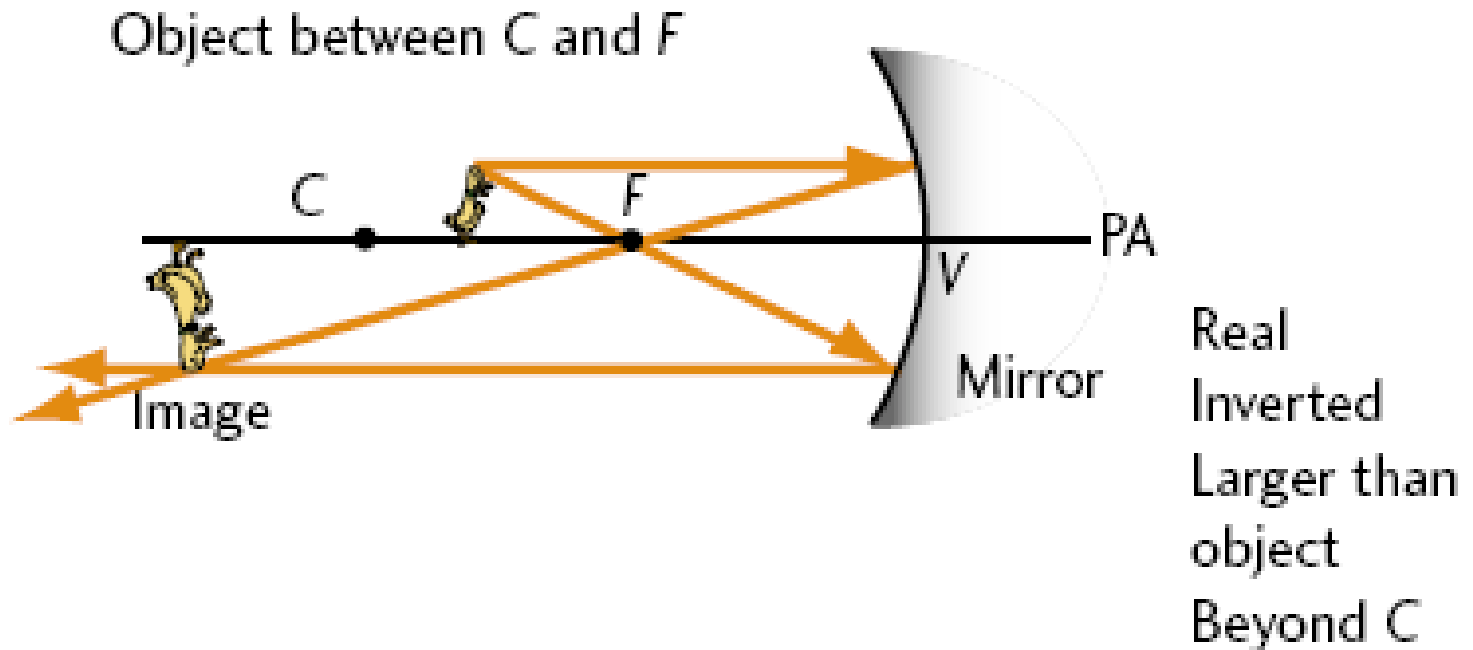
Object at C

Object at C

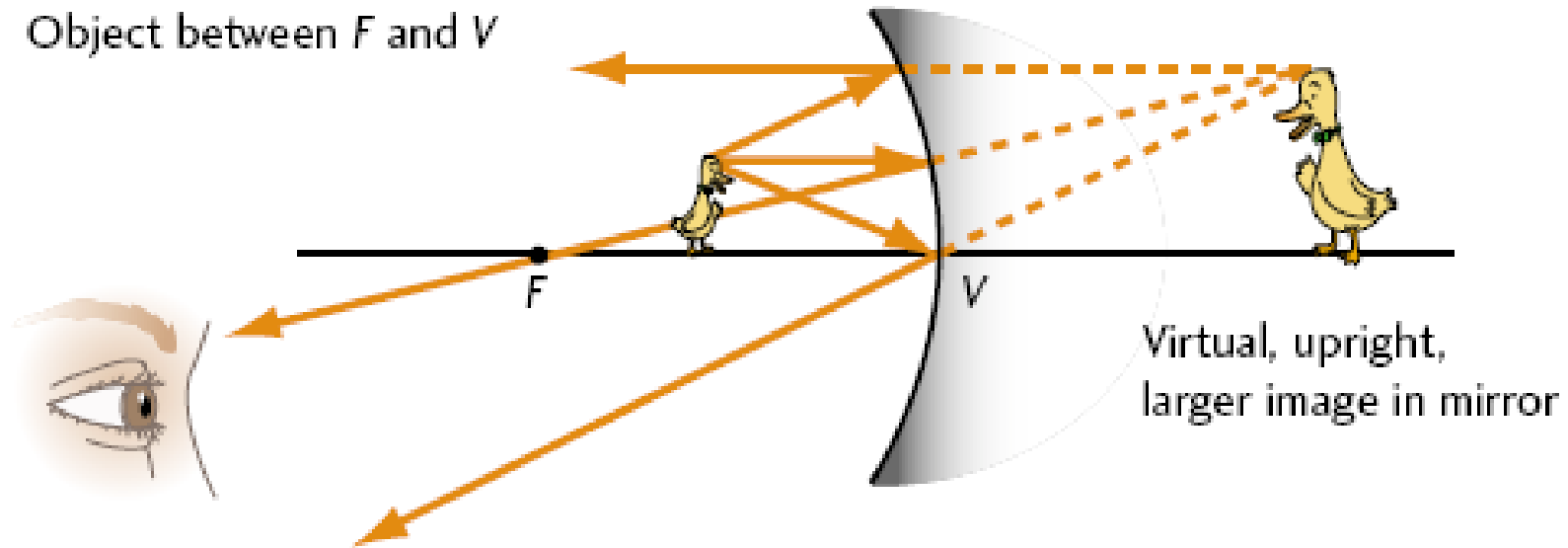


Real
Inverted
Same size
as object
At C

Object between C and F

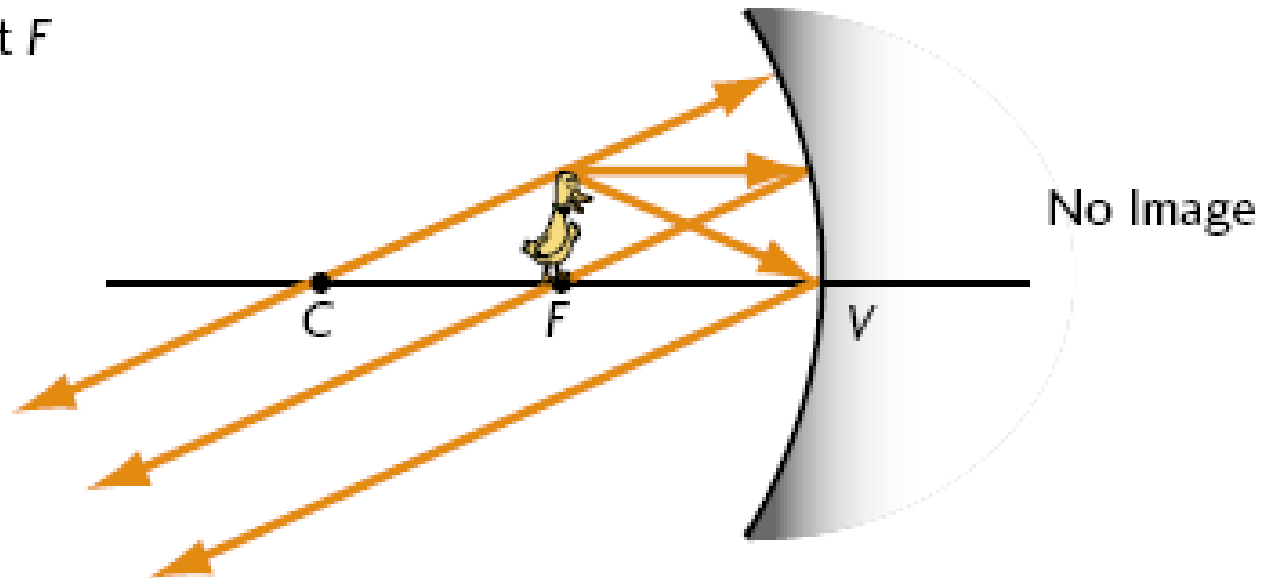


Object between F and V



Object at F

Object at F



Curved mirror equation

The curved mirror equation is

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

f = focal length

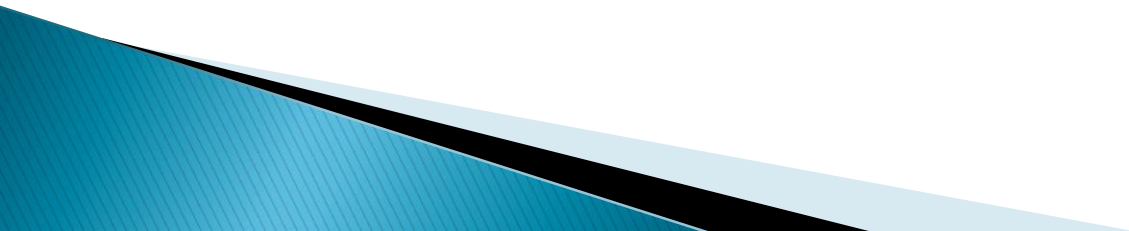
d = distance

i = image

o = object

Diverging Mirrors – Convex

- ▶ Convex mirrors are called diverging mirrors
- ▶ They produce virtual images
- ▶ State some uses of convex mirrors

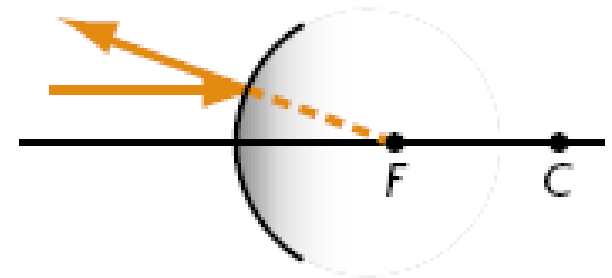


Images formed by convex mirrors

- ▶ Images parallel to the principal axis

Parallel to
principal axis

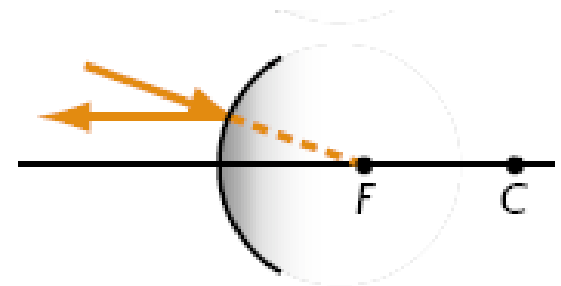
Reflects out, as though
coming from F



Incident ray directed at focus

Directed at
focus (F)

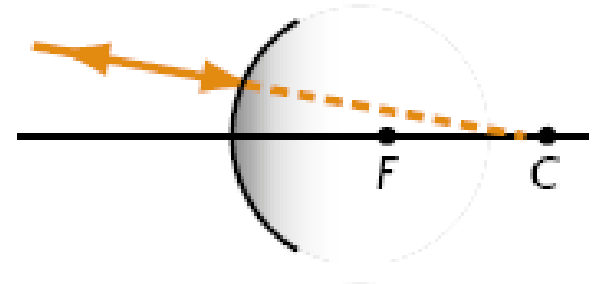
Reflects back parallel
to principal axis



Incident ray directed at centre of curvature

Directed at centre of curvature (C)

Reflects straight back
| on itself

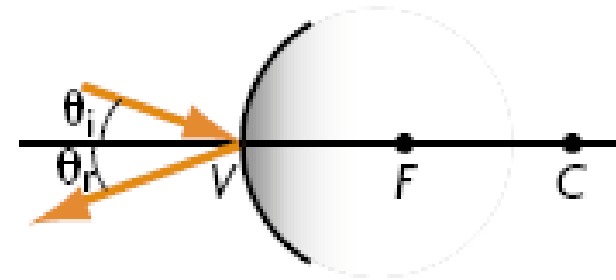


Incident ray directed at vertex

To vertex (V)

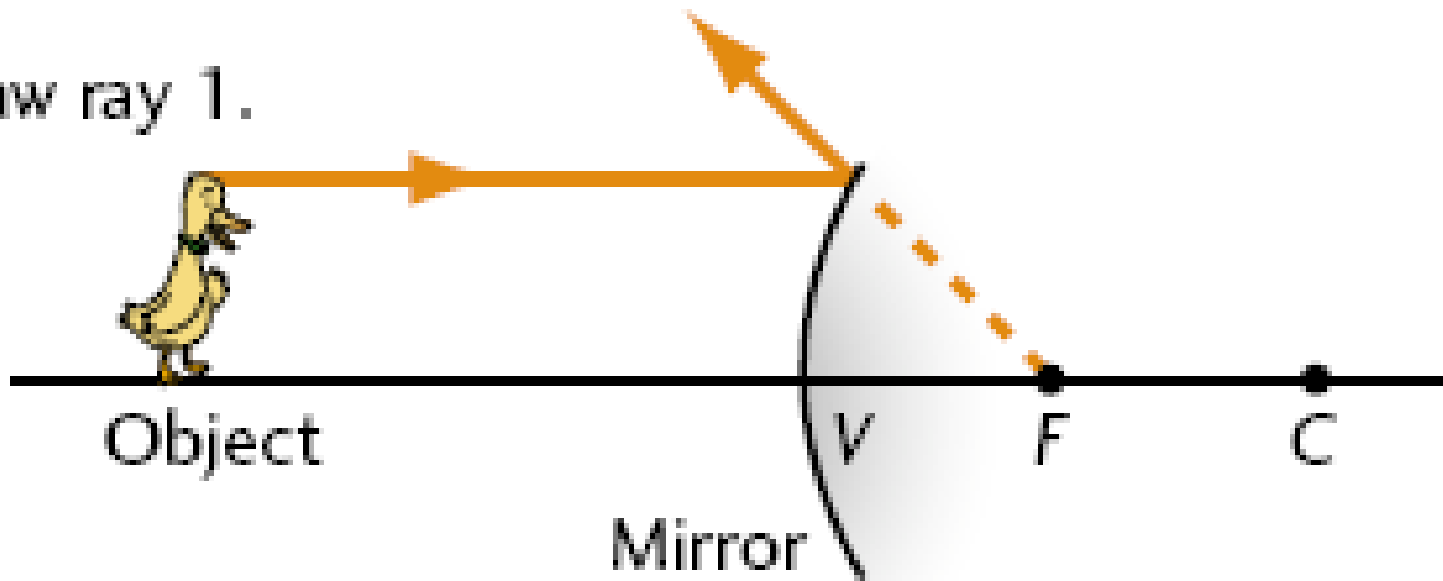
Plane mirror

$$\theta_i = \theta_r$$



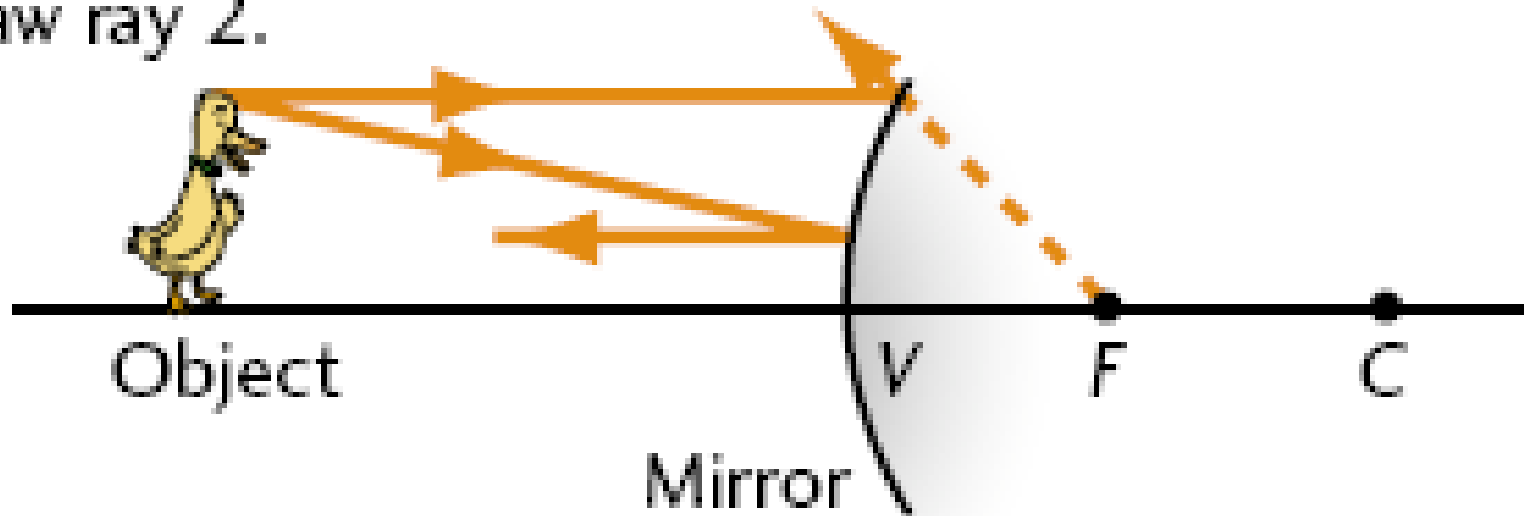
Comment on this ray diagram

Draw ray 1.



What are the properties of each of the reflected rays

Draw ray 2.



What are the properties of each of the reflected rays comment on the image formed

Draw the image.

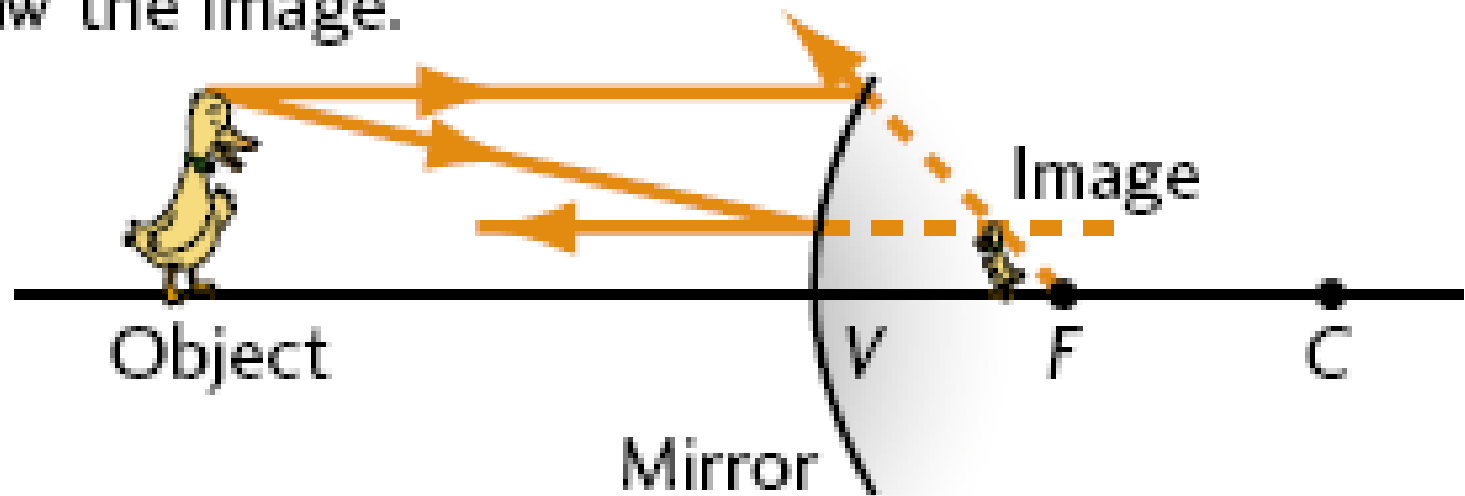
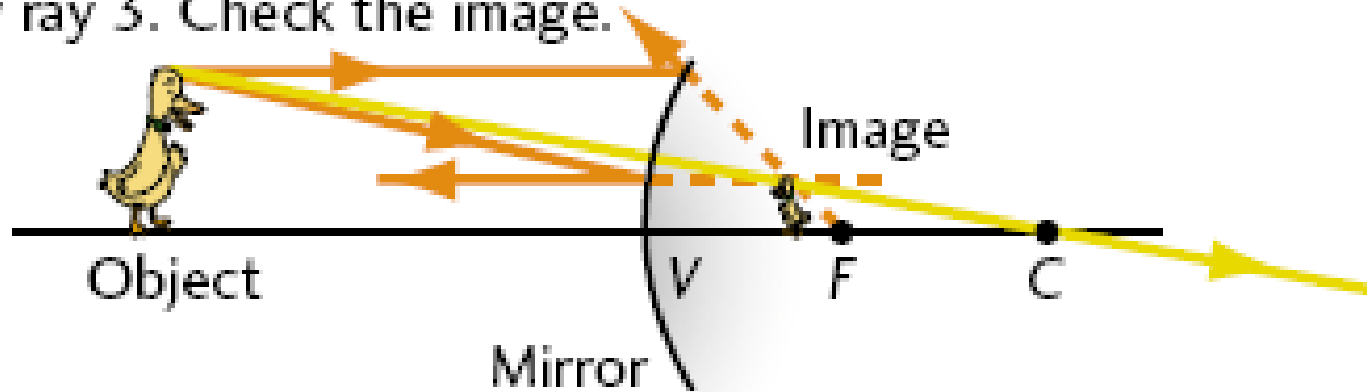


Image formed by a convex mirror

Draw ray 3. Check the image.



Centre of curvature

- ▶ How can you determine the centre of curvature and focus while drawing a ray diagram using a ray box and a convex mirror.